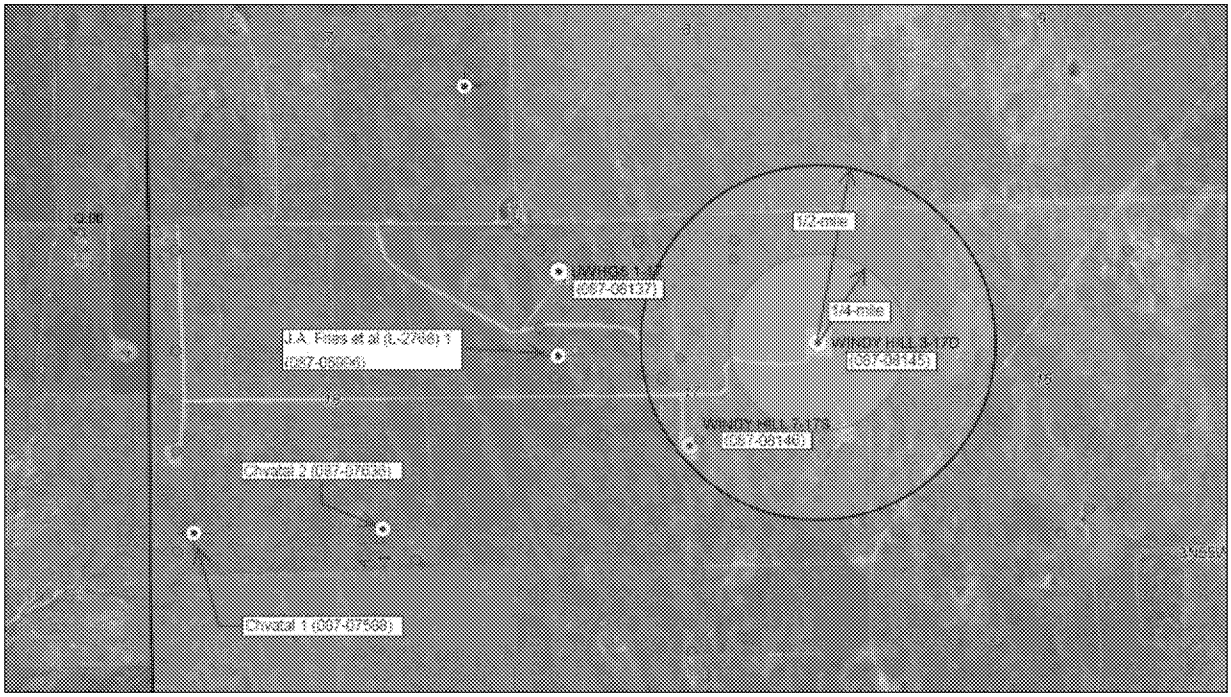
WINDY HILL WATER PRODUCTION PROJECT

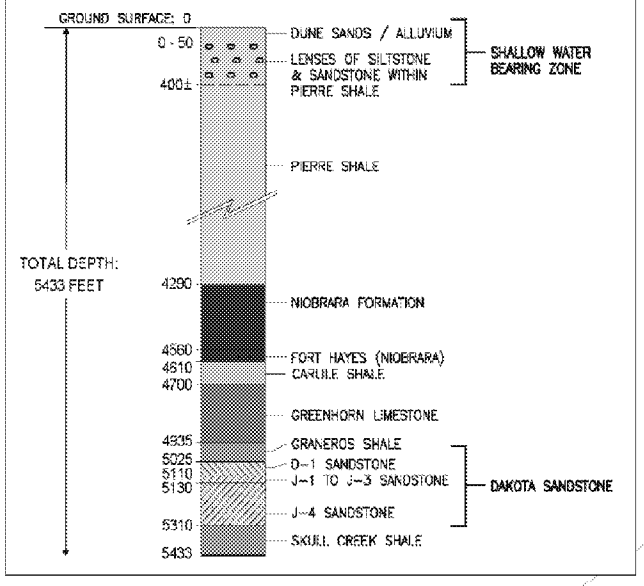
in Morgan County, Colorado

Groundwater Flow Modeling to Determine Aquifer Exemption Boundary



Windy Hill Project Area w-Air Photo_01072016.pdf

WINDY HILL
WATER PRODUCTION PROJECT



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During the permitting process, the Colorado Oil and Gas Conservation Commission (COGCC), United States Environmental Protection Agency (EPA), and the Colorado Division of Water Resources (DWR) requested "that Windy Hill create a hydrologic model predicting the effects of simultaneous injection and extraction from the J-Sandstone over a one hundred (100) year interval in the vicinity of the Windy Hill Water Facility in Morgan County."

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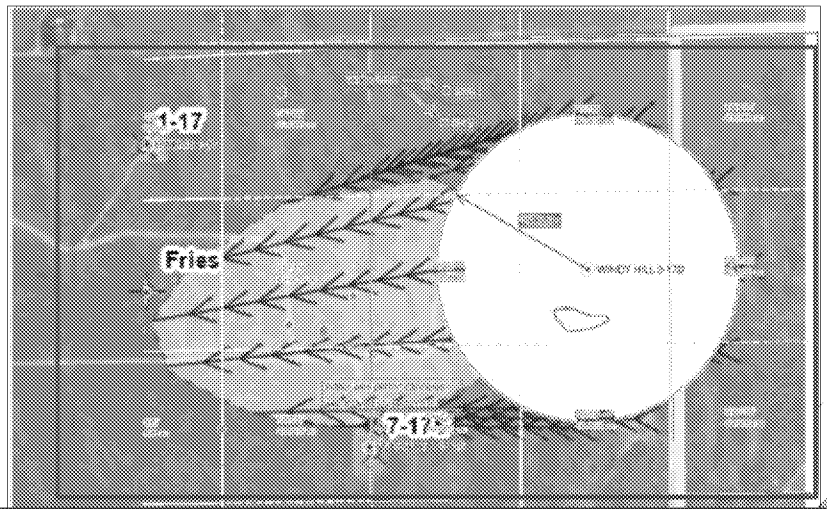
Specific questions to be addressed by the model included:

1. Will produced water injected into the J-Sandstone or groundwater naturally present in the J-Sandstone move upward through the boreholes of three existing wells (John A Fries et al (L-2768) #1 well [API #05-087-05996], UWHGS #1-17 [API #05-087-08137], and Windy Hill #7-17S [API #05-087-08146]) and affect shallow groundwater?

2. Will produced water injected into the J-Sandstone at the Windy Hill #3-17D well migrate west underground and be pumped out of the industrial supply water well?

3. What is the approximate area of the J- Sandstone which the injected water would occupy, as related to delimiting the aquifer exemption area?

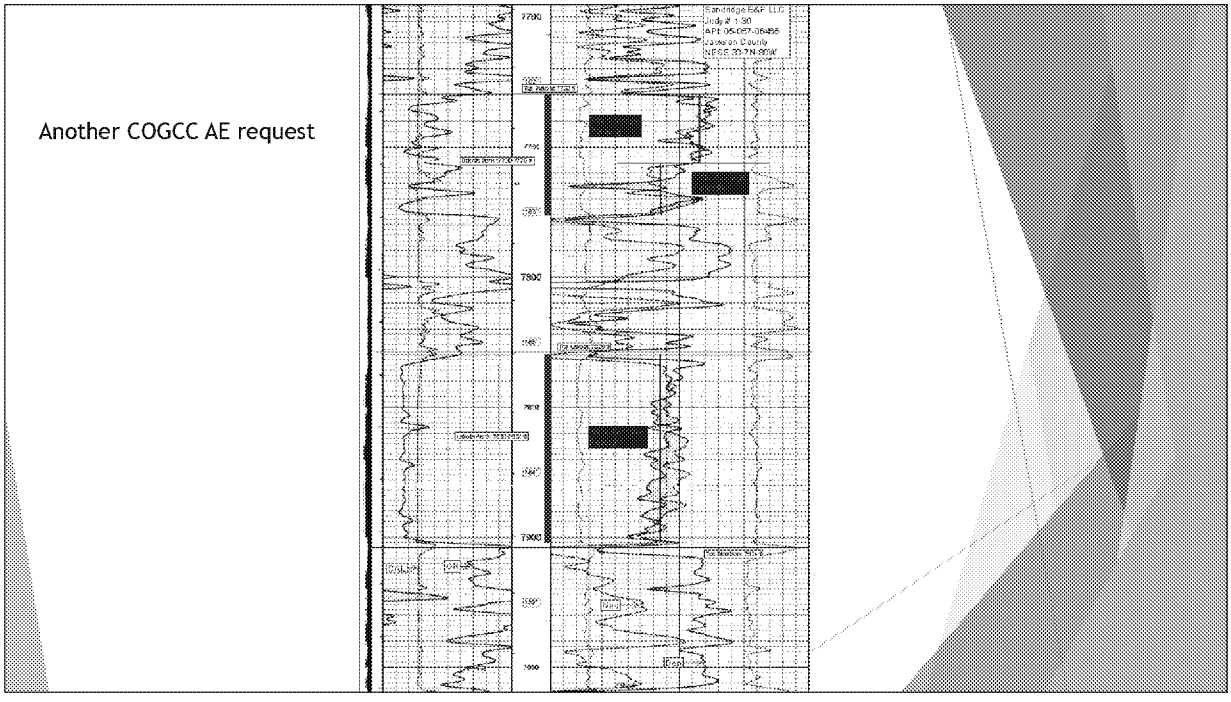
Tetra Tech developed a groundwater flow and particle tracking model using the MODFLOW and MODPATH model codes to simulate Windy Hill's proposed injection and groundwater withdrawal operations and answer the questions posed by the agencies.



Another COGCC AE request: Fill-up Volume Calculation

Sandridge E&P LLC					
Judy # 1-30					
API: 05-057-06466					
Jackson County					
NESE 30-7N-80W					
Dakota Formation		7730-7829 ft	99 ft		
	Perfs	7730-7776 ft	46 ft		
	Interval A:	7730-7755 ft	25 ft	7% porosity from Density/Neutron Log	
	Interval B:	7755-7776 ft	21 ft	13% porosity	
Lakota Formation		7829-7904 ft	75 ft		
	Perfs	7830-7902	72 ft		
	Interval C	7830-7902	72 ft	13% porosity	
Maximum Volume Calculation:					
Maximum Injection Volume =		(Radius^2 x Pi x Interval Thickness x Porosity) / 5.6146 bbl/ft^3			barrels
		Radius = 1/4-mile = 1320 ft			
		PI = π = 3.1514		Interval thickness in feet	
		Porosity = Φ = Decimal %, 1.00=100%			
		5.6146 = conversion factor cubic feet to barrels			
	Interval A	((1320)^2 x 3.1514 x 25 x 0.07)/5.6146 =			
				1,706,149	
	Interval B	((1320)^2 x 3.1514 x 21 x 0.13)/5.6146 =			
				2,661,592	
	Interval C	((1320)^2 x 3.1514 x 72 x 0.13)/5.6146 =			
				9,125,460	
			Total	13,493,201	barrels

Another COGCC AE request



Document Identifier	Type	Document Number	Description Name	Date	File Size (KB)	Download
05706466	Well Logs	1370377	Array Induction Log	11/10/2009	10285218	Download
05706466	Well Logs	1370378	GR Cement Bond Log	11/06/2009	2860238	Download
05706466	Well Logs	1370380	Mud Log	11/09/2009	7098698	Download
05706466	Well Logs	1370381	Hole Volume Caliper Log	11/09/2009	2228362	Download
05706466	Well Logs	1370382	Compensated Sonic Log	11/09/2009	7327518	Download
05706466	Well Logs	700041808	TIF-CALIPER	05/18/2009	3485643	Download
05706466	Well Logs	700041809	TIF-DENSITY	05/18/2009	4364531	Download
05706466	Well Logs	700041810	TIF-INDUCTION	05/18/2009	4994544	Download
05706466	Well Logs	700041811	TIF-COMBINATION OPEN HOLE	05/18/2009	8151583	Download
05706466	Well Logs	700041812	TIF-SONIC	05/18/2009	2237459	Download
05706466	Wells	1772480	CORRESPONDENCE	02/21/2013		Download
05706466	Wells	200379253	NOTICE OF ALLEGED VIOLATION	02/21/2013		Download
[redacted]	Facilities	400524858	RATIFICATION DOCUMENT	03/04/2013		Download
05706466	Well Logs	1305711	CEMENT BOND LOG	05/20/2011	3932695	Download
05706466	Wells	1772647	MECHANICAL INTEGRITY TEST	05/20/2013		Download
12332609	Wells	1536858	CORRESPONDENCE	08/07/2013		Download
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295300	Facilities	2026401	CORRESPONDENCE	10/14/2013	199476	Download
295300	Facilities	2483978	CERTIFICATION OF CLEARANCE - CHANGE OPERATOR	12/31/2013	273559	Download
05706466	Wells	460728199	NOTICE OF NOTIFICATION - MIT	11/09/2014	92073	Download
05706480	Wells	460966161	RATIFICATION DOCUMENT	12/14/2015	290168	Download
05706480	Wells	460950801	IDENTIFICATION DATA	12/14/2015	20375	Download
05706480	Wells	460952965	XML FILE	12/14/2015	17702	Download
05706466	Wells	461207521	FORM 33-INTENT-SUBMITTED	08/02/2016	91283	Download
05706466	Wells	461085356	WELLBORE DIAGRAM-PROPOSED	08/02/2016	46276	Download

DEWEY-BURDOCK DEEP INJECTION WELLS

For the disposal of ISR waste fluids treated to meet radioactive waste standards (set by the NRC) and hazardous waste standards

DEWEY-BURDOCK DEEP INJECTION WELLS

Table 3. Surface Casing Logs

TYPE OF LOG	PURPOSE	DUE DATE
Dual Induction Laterolog	12-1/4" open-hole formation evaluation	Prior to setting 9-5/8" casing
Gamma Ray	12-1/4" open-hole formation evaluation	Prior to setting 9-5/8" casing
BHC Sonic	12-1/4" open-hole formation evaluation	Prior to setting 9-5/8" casing
Formation Density	12-1/4" open-hole formation evaluation	Prior to setting 9-5/8" casing
Caliper	12-1/4" open-hole cement estimate	Prior to setting 9-5/8" casing
Pressure Bond Log[1]	Cement quality behind the 9-5/8" casing	Prior to setting 7" or 5-1/2" casing in PW No. 1 Prior to setting 5-1/2" casing in PW No. 3

[1] Recommendations for Cement Bond Log procedures can be found at https://www.epa.gov/uic/uic-epa-region-8. It is the responsibility of the Permittee to obtain and use guidance prior to conducting any well log or test required as a condition of this permit.

DEWEY-BURDOCK DEEP INJECTION WELLS

Table 4. Longstring Casing: Open Hole Logs

TYPE OF LOG	PURPOSE	DUE DATE
Mud Logging	8-1/2" open-hole formation evaluation	During drilling
Dual Induction Laterolog	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Spontaneous Potential	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Gamma Ray	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
BHC Sonic	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Formation Density	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Compensated Neutron	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Fracture Finder	8-1/2" open-hole formation evaluation	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3
Caliper	7-1/2" open hole cement estimate	Prior to setting 7" or 5-1/2" casing in DW No. 1 Prior to setting 5-1/2" casing in DW No. 3

DEWEY-BURDOCK DEEP INJECTION WELLS

Table 5. Longstring Casing Logs

Cement Bond Log*	Cement quality behind the 7" or 5-1/2" casing in DW No. 1 Cement behind the 5-1/2" casing in DW No. 3	Prior to receiving Limited Authorization to Inject
Casing Inspection Log	Casing quality of the 7" or 5-1/2" casing in DW No. 1 Casing quality of the 5-1/2" casing in DW No. 3	Prior to receiving Limited Authorization to Inject

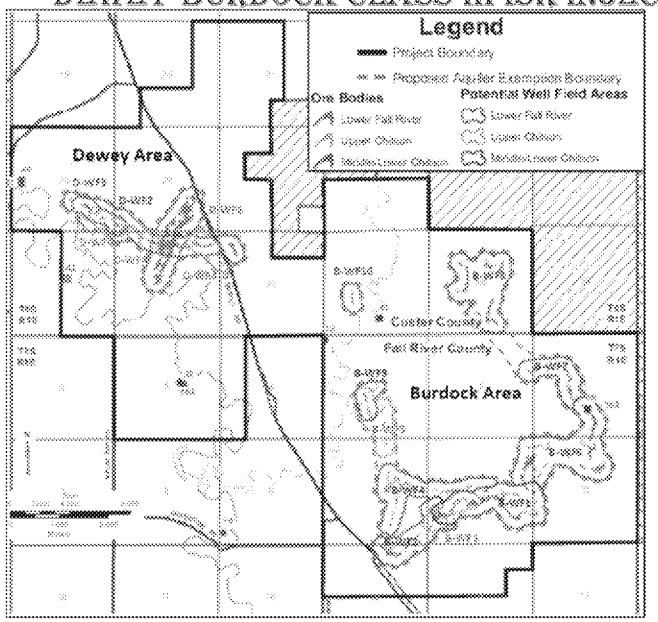

Figure 1. Map Showing the Dewey-Burdock Project Area and the Proposed AE Area

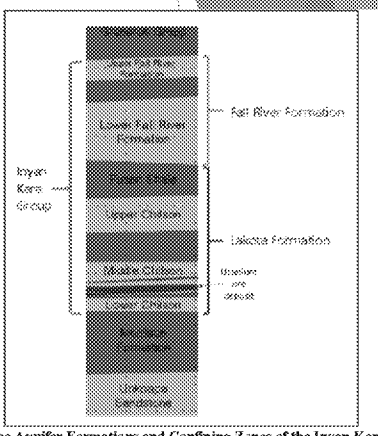

Figure 2. The Aquifer Formations and Confining Zones of the Inyan Kara Group.

DEWEY-BURDOCK CLASS III ISR INJECTION WELLS

Delineation and Pump Test Well Drillhole Logging Program

TYPE OF LOG	PURPOSE	DUE DATE
Gamma Ray	To identify ore depth and thickness	Prior to setting well casing
Self Potential	To identify confining zones and aquifer units.	Prior to setting well casing
Resistivity	To identify confining zone depth and thickness	Prior to setting well casing
Physical Geologic Log	To identify lithology and strata dips	During drilling

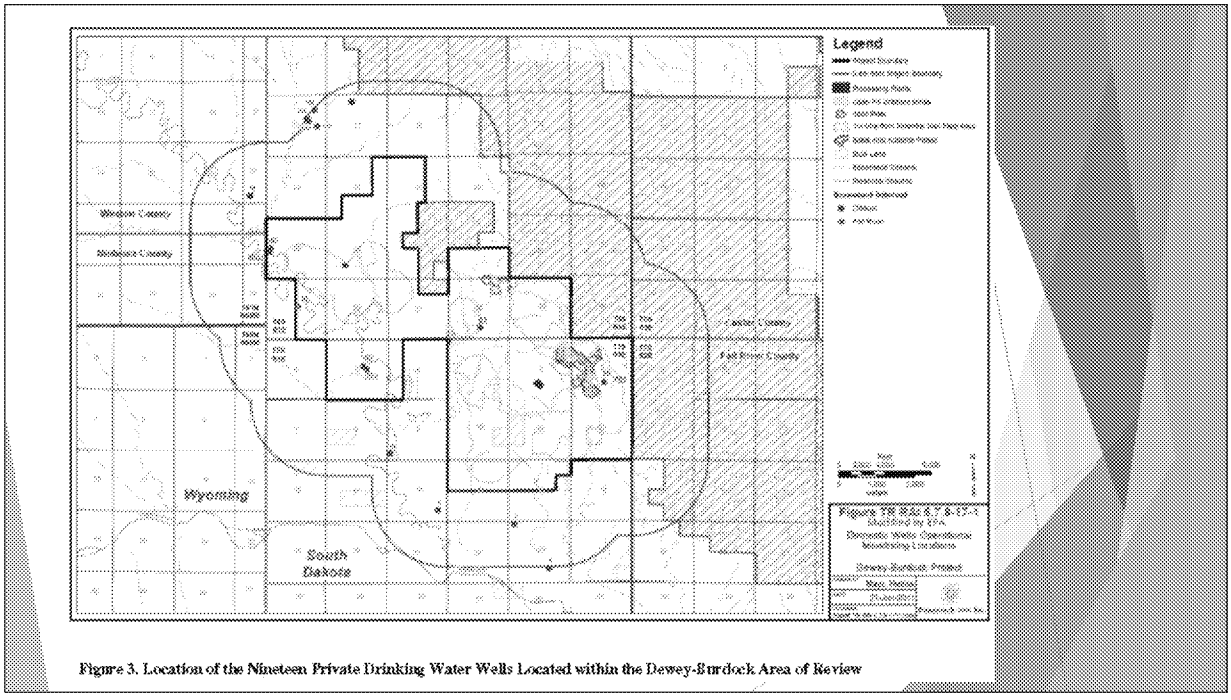

Figure 3. Location of the Nineteen Private Drinking Water Wells Located within the Dewey-Sturdock Area of Review

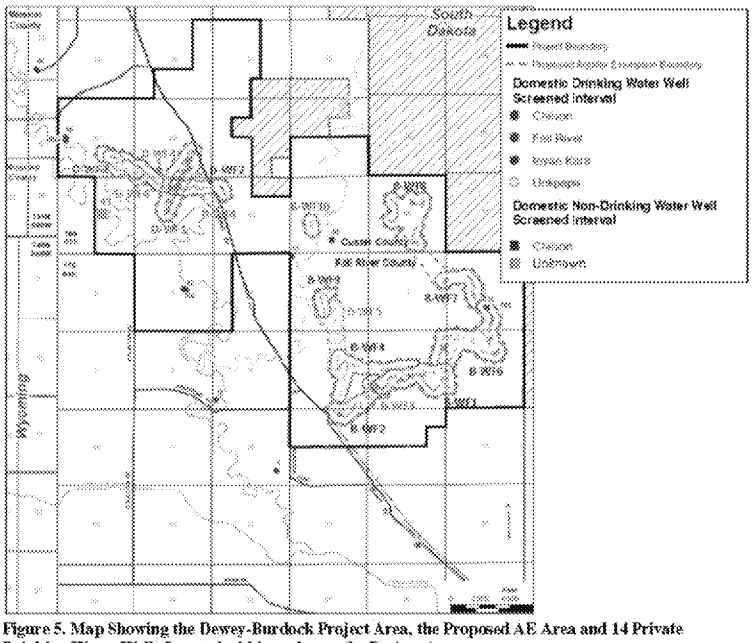

Figure 5. Map Showing the Dewey-Burdock Project Area, the Proposed AE Area and 14 Private Drinking Water Wells Located within and near the Project Area.

Equation for Calculating the Up-gradient Extent of a Well's Capture Zone: The first equation, which was used to calculate the up-gradient extent of the capture zone, is equation 4-7 in Section 4.4.3 of the EPA *Handbook on Ground Water and Wellhead Protection*. This equation is based on the Uniform Flow Equation and calculates the up-gradient extent of a "zone of contribution" (ZOC) surrounding a pumping well. When there is a slope in the aquifer potentiometric surface, the ZOC is asymmetric, extending farther up-gradient than down-gradient as illustrated in Figure 6. For the purposes of this CZA, the ZOC is considered to be the capture zone for the pumping well.
Ground Water and Wellhead Protection Handbook, EPA/625/R-94/001, September, 1994

$$t_x = n/Ki\,[r_x - (Q/2\pi Kbi)\ln\{1 + (2\pi Kbi/Q)r_x\}] \quad (4\text{-}7)$$

where
- t_x = travel time from point x to a pumping well
- n = porosity
- r_x = distance over which ground water travels in T_x. r_x is positive (+) if the point is upgradient, and negative (–) is downgradient
- Q = discharge
- K = hydraulic conductivity
- b = aquifer thickness
- i = hydraulic gradient

Transmissivity T=Kb,